

ORGANIC THIOL METAL-FREE STABILIZERS AND PLASTICIZERS FOR HALOGEN-CONTAINING POLYMERS

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CROSS REFERENCE

This application is a continuation-in-part application of U. S. Patent Application Serial Number 09/737,973 filed December 15, 2000 for "Organic Thiol Metal-Free Stabilizers and Plasticizers for Halogen-Containing Polymers."

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FIELD OF THE INVENTION

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The present invention relates to aliphatic and aromatic organic thiol compounds and the preparation thereof. The organic thiol compounds can be utilized to plasticize and/or stabilize halogen-containing polymer compositions, especially poly(vinyl chloride) compositions. The compounds of the present invention are ideally utilized in polymers normally susceptible to deterioration and color change which can occur during processing of the polymer or exposure of the polymer to certain environments and surprisingly also serve as excellent plasticizers.

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BACKGROUND OF THE INVENTION

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It is well known that chlorine-containing resins, particularly poly(vinyl chloride) polymers and copolymers, are unstable to heat and light and that the physical properties thereof are degraded upon exposure thereto. This degradation is typically manifested by development of or change in color. It is particularly noticeable in unstabilized polymers, i.e., polymers which do not contain stabilizers. Degradation or discoloration during processing is

particularly undesirable in clear or lightly colored plastics. Therefore, it is desirable to prevent or inhibit the discoloration of plastics during processing so as to achieve useful products free of discoloration.

5 In order to minimize the discoloration and deterioration of various halogen-containing polymers such as vinyl chloride polymers and copolymers, various stabilizers such as lead-, cadmium-, and tin-based stabilizers have been developed and utilized. However, in recent years environmental pollution caused by the toxicity of the heavy metal residues and ecological considerations have stimulated further evaluation of such
10 compounds and generated a search for alternative approaches.

Various compounds have been proposed for use in stabilizing halogen- containing polymers:

U. S. Patent No. 3,928,285 to Gough et al. relates to a synergistic stabilizer composition comprising an organotin borate and an organic thiol.

15 U. S. Patent No. 4,948,827 to Christidis relates to a thiophenol, prepared by reduction of tertiary butyl-4-toluenesulfonyl-2-chloride with the zinc-sulfuric acid couple, which reportedly can be used as a stabilizer for vinyl chloride polymers, as a chain-transfer agent, and as a peptizer.

European Patent Application No. EP 0 890 608 A2 relates to both
20 flexible and rigid vinyl chloride polymer compositions incorporating a latent mercaptan-containing heat stabilizer which are reportedly substantially free from the offensive odor typically associated with mercaptans and are

protected during processing by the degradation products of the latent (i.e., blocked) mercaptan, which include a free mercaptan. The free mercaptan thus released reportedly enhances the activity of metallic-based heat stabilizers such as zinc carboxylates and organotin carboxylates and mercaptides in the polymer composition. Other products of the degradation are believed to include carbocations of the blocking moiety which are stabilized by a molecular structure in which the electron deficiency is shared by several groups. The latent mercaptan comprises a 2-S-(tetrahydropyranyl)thioalkanol or a carboxylic acid ester thereof.

European Patent Application No. EP 0 945 484 A1 relates to compositions comprising halogen-containing polymers such as PVC resins which are reportedly stabilized against heat by a synergistic combination of a free mercaptan and a metal-based stabilizer and/or a Lewis acid such as zinc chloride.

SUMMARY OF THE INVENTION

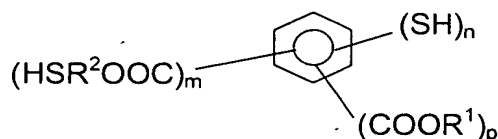
Organic thiol compounds and routes for their preparation are disclosed herein. The organic thiol compounds of the present invention, when blended with a halogen-containing polymer such as poly(vinyl chloride) or derivatives thereof, provide numerous advantages which include serving as plasticizers, stabilizers, and dehydrochlorination retarders. The organic thiol compounds of the present invention have a substantially reduced or even lack a characteristic odor typically associated

with thiol compounds. The present invention relates to both aromatic and aliphatic organic thiols.

DESCRIPTION OF THE PREFERRED EMBODIMENT

AROMATIC

5 The organic thiols of the present invention are aromatic compounds having at least one sulfhydryl group attached either directly or indirectly to an aromatic ring. The aromatic compound may contain one or more aromatic rings and at least one sulfhydryl substituent, as well as other groups such as an ester group, and the like. The organic thiols can
10 generally be described by the formula:



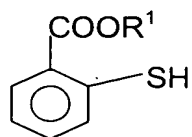
Formula I

15 wherein R^1 and R^2 , independently, comprise straight chain or branched alkyls having from 1 or 2 to about 15 carbon atoms, and preferably from about 4 to about 15 carbon atoms, or an aromatic or a substituted aromatic having from about 6 to about 15 carbon atoms and wherein, independently,
20 n is either 0, 1, 2, or 3, m is either 0, 1, 2, or 3, and p is either 0, 1, 2, or 3, with the proviso that $m+n+p=6$ or less. It is to be understood that when, independently, m, n, and/or p are greater than 1, the individual repeat groups are each attached to a different carbon atom on the benzene ring.

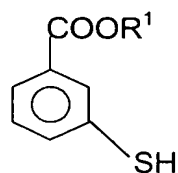
Independent exemplifications of R^1 and R^2 are 2-ethylhexyl, isooctyl, isodecyl, benzyl and butyl.

Examples of compounds which can be formed from the above formula include:

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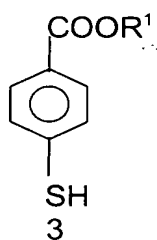


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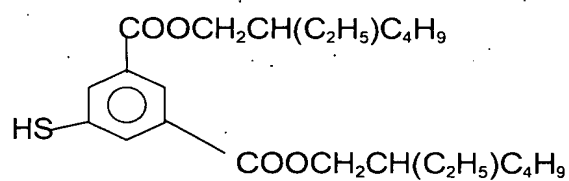


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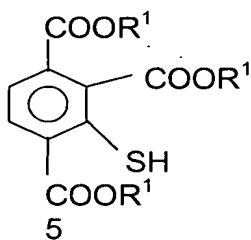
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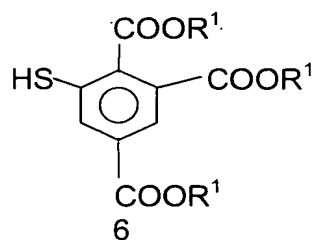
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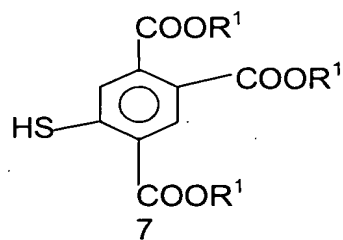
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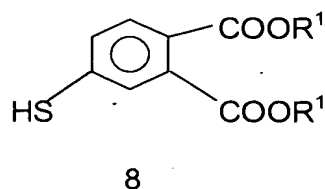
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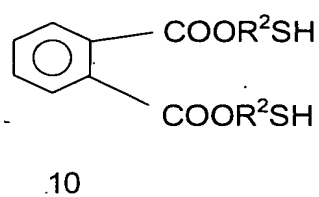
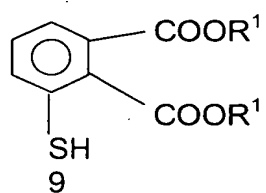
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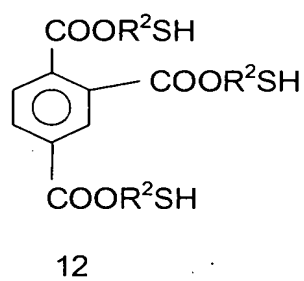
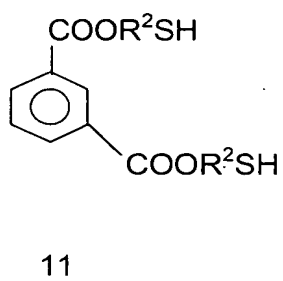
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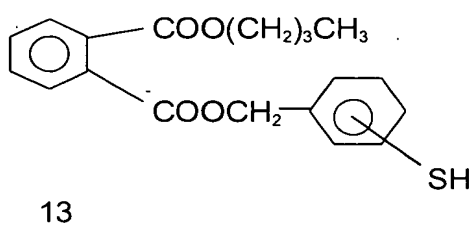


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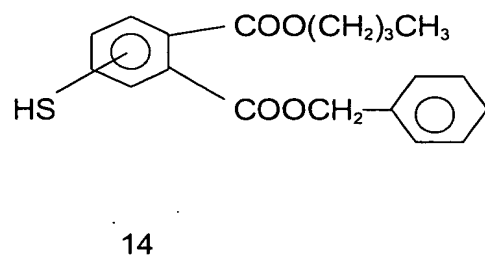
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The various compounds of the above-disclosed general formula wherein $m=0$ can be synthesized substantially as follows. In a first step, a desired amount of an hydroxy aromatic acid is placed in a reaction vessel together with a large molar excess of an alcohol having from 1 to about 3 carbon atoms, preferably methanol or ethanol. From about 0.05 to about 0.5 mole, per mole of the starting acid, of a very strong acid, i.e., one having a concentrated pH of at least 1 to about 3, such as H_2SO_4 , para-toluenesulfonic acid, or hydrochloric acid, is added to the mixture, and the mixture is then heated either under air or preferably under inert conditions, such as under nitrogen, generally to the reflux temperature of the alcohol, for a sufficient length of time until the reaction is complete, a condition which can be established through periodic analysis.

The hot solution is then poured into a quantity of ice water. Then, the precipitate is filtered off and washed on the filter until the pH of the wash liquid is neutral. The filtered product is then dried to give an hydroxy aromatic ester, which can be purified further by conventional methods, if desired.

A desired amount of the above-noted ester is added to a reaction vessel along with an *N,N*-dialkylthiocarbamoyl halide such as *N,N*-dimethylthiocarbamoyl chloride (about 1-3 moles per mole of ester), a base such as DABCO (about 1-3 moles per mole of ester), and *N,N*-

dimethylformamide (about 1-3 liters per mole of ester). The mixture is stirred at room temperature (e.g., 15°C to about 30°C) for a suitable reaction time, and a suitable quantity of water is then added to induce precipitation of a solid which is filtered off and washed on the filter until the pH of the wash liquid is neutral. The resulting second step intermediate product (the corresponding O-substituted *N,N*-dimethylthiocarbamate) is subsequently dried.

The second step intermediate product is transferred to a suitable reaction vessel and heated preferably in an oil bath or the like to a temperature from about 180°C to about 250°C and desirably from about 220°C to about 235°C until the reaction is complete, generally in about 20 minutes to about 2 hours. Then, after cooling to about 60°C to about 90°C, the reaction vessel is purged with nitrogen or other chemically unreactive gas, and an aqueous solution of a base such as NaOH or KOH is subsequently added in an amount that is at least sufficient to cause hydrolysis of the thiocarbamate and ester groups. The mixture is heated under reflux to induce complete reaction and then cooled to room temperature and acidified to a pH generally less than 4 in any manner such as with a 10 percent aqueous solution utilizing an acid as stated above. The recovered mercapto acid product from the third step is washed with suitable quantities of water and dried, preferably under a vacuum.

In the final step of the synthesis, the intermediate product from the third step is added to a reaction vessel equipped with a suitable stirring apparatus, a water separator, and a reflux condenser, along with an alkyl alcohol having from 1 to 15 carbon atoms in an amount from about 1 to about 2 molar equivalents per carboxyl group in the mercapto acid, benzene or other suitable entraining agent for water (about 0.5 to 2 L per mole of mercapto acid), and a strong acid (about 0.1 to 0.3 mole per mole of mercapto acid) as defined above. The mixture is heated to the reflux temperature for a sufficient time to induce extensive reaction, typically approximately three hours, or until all the solid is dissolved. The solution is cooled to room temperature and poured into ice water, and the organic layer is washed in succession with a NaHCO_3 or Na_2CO_3 solution and water. The organic layer is dried over a drying agent such as anhydrous MgSO_4 . The dried solution is decolorized with activated carbon, filtered, and distilled to remove the benzene and other volatile impurities. The final product is generally an oil or low melting solid having a structure defined by the general formula of the present invention.

When m in the general formula is unequal to 0, the HSR^2OOC groups of the thiols of this invention can be introduced by the direct esterification of COOH groups with thioalkanols (HSR^2OH), using methods that are well-known to those skilled in the art. For example, compound 11

in which R^2 is $-(CH_2)_6-$ has been prepared by the esterification of isophthalic acid with two molar equivalents of 6-mercapto-1-hexanol in the presence of a catalytic amount of concentrated H_2SO_4 .

5 Bis(2-ethylhexyl) 5-mercaptoisophthalate is one such compound which is disclosed by the general formula of the present invention when n is 1, m is 0, p is 2, and R^1 is 2-ethylhexyl, and is also shown as specific formula 4. The synthetic route disclosed hereinbelow for preparation of the bis(2-ethylhexyl) 5-mercaptoisophthalate compound is based in part on a Newman-Kwart reaction, as in the general route described above.

10 Bis(2-ethylhexyl) 5-mercaptoisophthalate can be synthesized as follows:

To a 1-L round-bottom flask equipped with a magnetic stirring bar were added 187.8 g (1 mol) of 5-hydroxyisophthalic acid commercially available from Aldrich (purity approximately 97%) and 500 mL (12.3 mol) of 15 methanol. After the addition of 28 mL of concentrated H_2SO_4 , the mixture was heated to the reflux temperature and stirred under reflux for 4 hours. The hot solution was poured into 500 mL of ice water. Then, the white solid product was filtered off and washed on the filter with several portions of water until the pH of the wash liquid was neutral. The product was dried 20 under vacuum, preferably at $60^\circ C$ overnight, to give 206.8 g of dimethyl 5-hydroxyisophthalate. Testing on the composition revealed the following data: mp $164-166^\circ C$; GC purity >99%; yield 98.2%; 1H NMR (in $CDCl_3$ +

DMSO- d_6 w/TMS, ppm): 3.68 (s, 6 H, OCH₃), 7.45 (s, 2 H, CH), 7.89 (s, 1 H, CH), 9.35 (broad, 1 H, OH); $\{^1\text{H}\}^{13}\text{C}$ NMR (in CDCl₃ + DMSO- d_6 w/TMS, ppm): 51.92 (OCH₃), 120.50 (C4, C6), 121.10 (C2), 131.15 (C1, C3), 157.36 (C5), 165.85 (COOR); ^1H - ^{13}C NMR (in CDCl₃ + DMSO- d_6 w/TMS, ppm):
 5 51.92 (quartet, OCH₃, $^1J_{\text{CH}} = 147$ Hz), 120.50 (d, C4, C6, $^1J_{\text{CH}} = 164.4$ Hz),
 121.10 (d, C2, $^1J_{\text{CH}} = 168.3$ Hz), 131.15 (s, C1, C3), 157.36 (s, C5), 165.85 (s, COOR); GC-MS (in acetone): 210 (M⁺).

To a 150-mL round-bottom flask equipped with a magnetic stirring bar were added dimethyl 5-hydroxyisophthalate, *N,N*-dimethylthiocarbamoyl
 10 chloride, DABCO (1,4-diazabicyclo[2.2.2]octane), and 50 mL of *N,N*-dimethylformamide. The mixture was stirred at room temperature for 5 hours, and 100 mL of water then was added slowly. The orange solid gradually disappeared, and the solution became light brown. An additional 100 mL of water was added to induce the precipitation of a white solid,
 15 which was filtered off and washed on the filter with portions of water until the pH of the wash liquid was neutral. The product was dried, preferably under vacuum at 60°C overnight, to give 1-O-3,5-bis(methoxycarbonyl)phenylene *N,N*-dimethylthiocarbamate as a white powder. Testing of the compound revealed the following: mp 114.5-
 20 116.5°C; ^1H NMR (in CDCl₃ w/TMS, ppm): 3.38 (s, 3 H, NCH₃), 3.46 (s, 3 H, NCH₃), 3.94 (s, 6 H, OCH₃), 7.93 (s, 2 H, CH), 8.58 (s, 1 H, CH); $\{^1\text{H}\}^{13}\text{C}$ NMR (in CDCl₃ w/TMS, ppm): 38.85 (NCH₃), 43.39 (NCH₃), 52.51 (OCH₃),

127.96 (C4), 128.36 (C2, C6), 131.54 (C3, C5), 153.86 (C1), 165.30 (COOR), 186.84 (OC(S)NR₂).

As shown by the following table, reaction yield for 1-O-3,5-bis(methoxycarbonyl)phenylene *N,N*-dimethylthiocarbamate varied as a function of the molar ratio of the reactants.

Table 1
Molar Ratio of the Reactants vs. Reaction Yield

Dimethyl Ester, ^a g (mmol)	<i>N,N</i> -Dimethyl- thiocarbamoyl Chloride, g (mmol)	DABCO, g (mmol)	Molar Ratio	Yield, g (%)
5.50 (26.2)	9.60 (77.0)	8.70 (77.0)	1/3/3	7.60 (97.7)
5.00 (23.8)	3.30 (26.2)	8.00 (71.4)	1/1.1/3	6.54 (92.5)
5.00 (23.8)	3.30 (26.2)	5.34 (47.6)	1/1.1/2	6.42 (90.7)
5.00 (23.8)	2.95 (23.8)	2.95 (26.3)	1/1/1.1	5.13 (72.4)
4.82 (22.9)	3.12 (25.2)	3.86 (34.4)	1/1.1/1.5	4.38 (64.0)

^a = Dimethyl 5-hydroxyisophthalate.

In a test tube containing a magnetic stirring bar, 0.1 g (0.336 mmol) of 1-O-3,5-bis(methoxycarbonyl)phenylene *N,N*-dimethylthiocarbamate was heated in an oil bath at a constant temperature, preferably about 230-235°C, for a selected time, preferably at least 20 minutes. As can be seen from the following table, reaction yield varied as a function of time and temperature.

Table 2
Reaction Yield of 1-S-3,5-bis(methoxycarbonyl)phenylene *N,N*-dimethylthiocarbamate As a Function of Temperature and Time

Temperature, °C	Time, min	Yield, % ^a
176	20	No reaction
200	20	<5
208	20	<5
220	20	30
230	20	55
240	20	Decomposition
230	40	75
230	60	90
232	60	>90
232	90	95
232-235	60	100
232-235	90	100
232-235	120	100

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^a The yields were determined by comparing the proton NMR signal intensities of the $-N(CH_3)_2$ groups of the starting material and the product.

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The white solid first melted into a yellowish oil, then gradually became dark brown. After cooling to room temperature, a tar-like solid was obtained. Recrystallization from methanol gave 1-S-3,5-bis(methoxycarbonyl)phenylene *N,N*-dimethylthiocarbamate as a gray solid having the following characteristics: mp 117-118°C; ¹H NMR (in CDCl₃ w/TMS, ppm): 3.06 (s, 3 H, NCH₃), 3.12 (s, 3 H, NCH₃), 3.94 (s, 6 H, OCH₃), 8.34 (s, 2 H, CH), 8.69 (s, 1 H, CH); {¹H}¹³C NMR (in CDCl₃ w/TMS, ppm): 37.06 (N(CH₃)₂), 52.53 (OCH₃), 130.90 (C4), 131.44 (C3, C5), 131.58 (C2, C6), 140.87 (C1), 165.81 (COOR), 165.94 (SC(O)NR₂); ¹H-¹³C NMR (in CDCl₃ w/TMS, ppm): 37.06 (quartet, N(CH₃)₂, ¹J_{CH} = 139.6 Hz), 52.53 (quartet, OCH₃, ¹J_{CH} = 147.34 Hz), 130.90 (doublet of triplets, C4, ¹J_{CH} = 167.65 Hz, ³J_{CH} = 6.448 Hz), 131.44 (C3, C5), 131.58 (doublet of doublets,

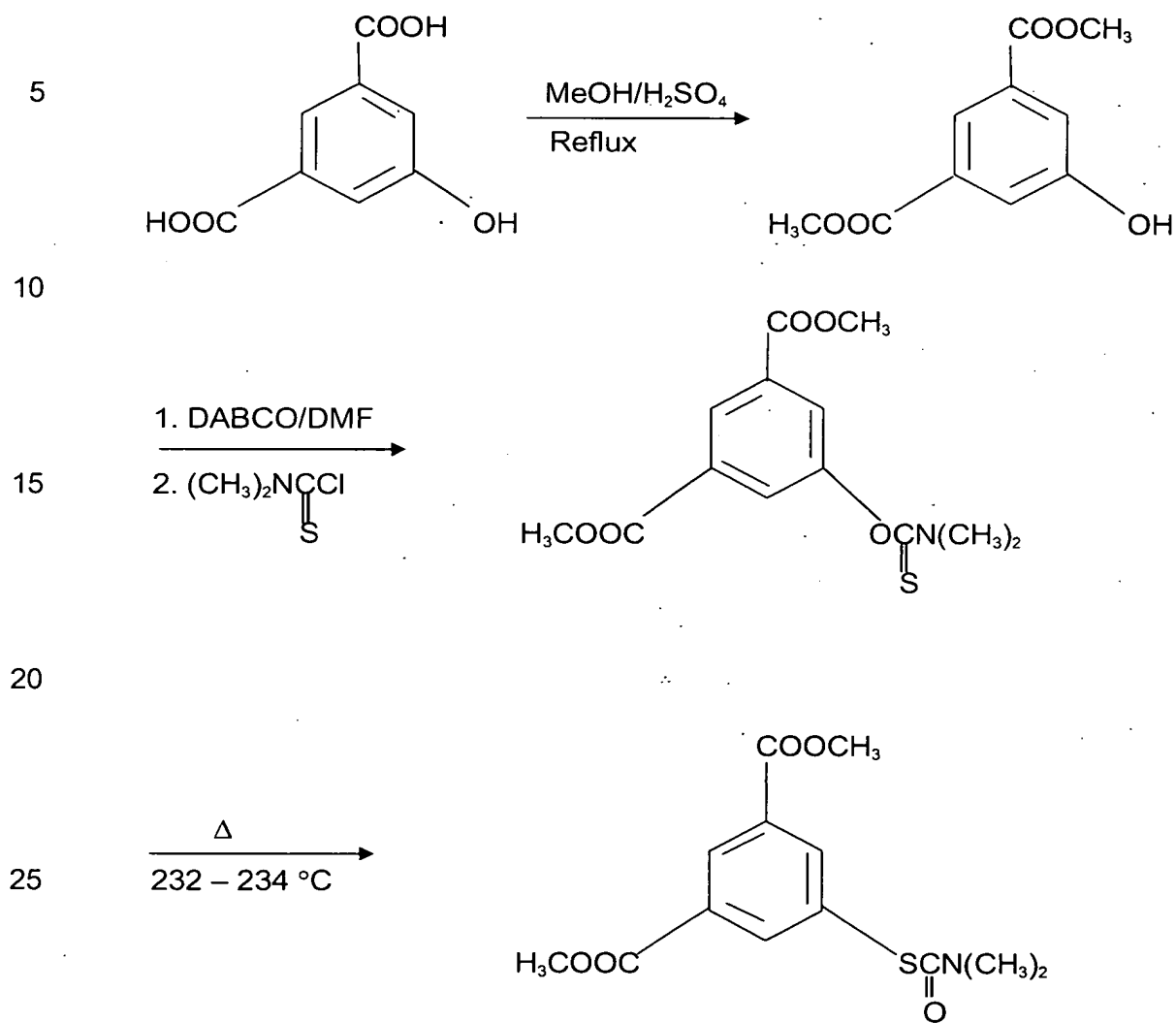
C2, C6, $^1J_{\text{CH}} = 168.3$ Hz, $^3J_{\text{CH}} = 6.448$ Hz), 140.87 (C1), 165.81 (COOR), 165.94 (SC(O)NR₂).

The 1-O-3,5-bis(methoxycarbonyl)phenylene *N,N*-dimethylthiocarbamate (112.2 g, 0.377 mol) was placed in a 2-L two-necked round-bottom flask equipped with a magnetic stirring bar, a condenser, and a thermometer. The flask was submerged in an oil bath preheated to 232-234°C and kept at that temperature for 2 hours. The resulting dark brown oil was allowed to cool to about 80°C. Then the thermometer was replaced by a gas inlet tube, and the system was purged with nitrogen before 850 mL of 2.7 N NaOH was added. The mixture was heated under reflux for 2 hours, cooled to room temperature, and acidified to pH <4 with 10% aqueous HCl. Then the beige solid product was washed, preferably 3 times, with 400-mL portions of water and dried under vacuum at 60-70°C to obtain 5-mercaptoisophthalic acid. Testing of the compound revealed the following properties: yield 67.5 g (90.3%); mp 240-246°C; ^1H NMR (in DMSO-d₆ w/TMS, ppm): 3.02 (s, 1 H, SH), 8.24 (s, 2 H, CH), 8.37 (s, 1 H, CH), 13.50 (broad, 2 H, COOH); $\{^1\text{H}\}^{13}\text{C}$ NMR (in DMSO-d₆ w/TMS, ppm): 129.43 (C2), 130.88 (C4, C6), 134.74 (C1, C3), 136.51 (C5), 166.91 (COOH); ^1H - ^{13}C NMR (in DMSO-d₆ w/TMS, ppm): 129.43 (d, C2, $^1J_{\text{CH}} = 167.39$ Hz), 130.88 (d, C4, C6, $^1J_{\text{CH}} = 165.27$ Hz), 134.74 (C1, C3), 136.51 (C5), 166.91 (COOH).

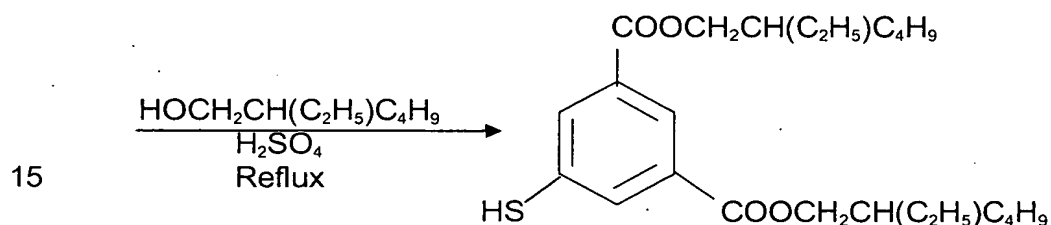
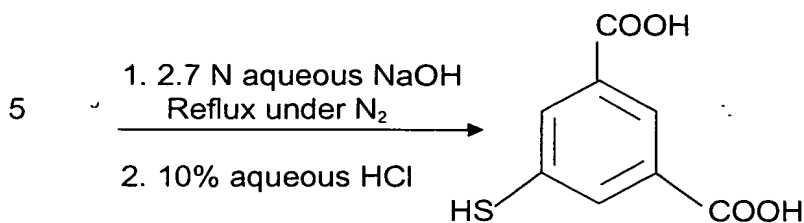
In the final step of the synthesis, to a 1-L round-bottom flask equipped with a magnetic stirring bar, a water separator, and a condenser were added 65.1 g (0.328 mol) of powdered 5-mercaptosiphthalic acid, 113 mL (94.2 g, 0.723 mol) of 2-ethyl-1-hexanol, 200 mL of benzene, and 4 mL of concentrated H_2SO_4 . After the mixture had been heated under reflux for a sufficient time, approximately 3 h, about 12 mL (0.67 mol) of water had been collected by the water separator. The mixture was allowed to reflux until all of the solid was dissolved, generally about 24 hours, and a dark brown solution was obtained. After cooling to room temperature, the solution was poured into ice water, and the organic layer was washed in succession with 50 mL of saturated NaHCO_3 solution and two 50-mL portions of water. The organic layer was dried over anhydrous MgSO_4 , and the dried solution was decolorized with ca. 10 g of activated carbon. After filtration, most of the benzene was removed by distillation at atmospheric pressure, and the excess 2-ethyl-1-hexanol and a trace amount of benzene were then removed by distillation at about 1 torr. The residual oil was bis(2-ethylhexyl) 5-mercaptosiphthalate. Testing on the compound revealed the following data: yield 132.7 g (95.5%); GC purity >89%; ^1H NMR (in CDCl_3 w/TMS, ppm): 0.94 (m, 8 H, CH_2), 1.40 (m, 20 H, CH_2CH_3), 1.75 (m, 2 H, CH), 3.77 (s, 1 H, SH), 4.28 (d, 4 H, CH_2), 8.11 (s, 2 H, CH), 8.43 (s, 1 H, CH); $\{^1\text{H}\}^{13}\text{C}$ NMR (in CDCl_3 w/TMS, ppm): 11.125 (C6'/C8'), 14.031 (C6'/C8'), 23.050 (C5'/C7'), 24.211 (C5'/C7'), 29.154 (C3'/C4'), 30.760

(C3'/C4'), 39.196 (C2'), 68.107 (C1'), 127.87 (C2), 132.23 (C1, C3), 133.09 (C5), 134.14 (C4, C6), 165.47 (COOR); GC-MS (in acetone): 422 (M^+).

The reaction sequence for the synthesis just described is as follows:

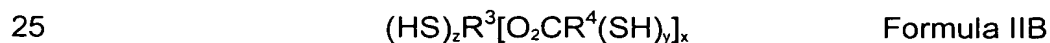


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ALIPHATIC

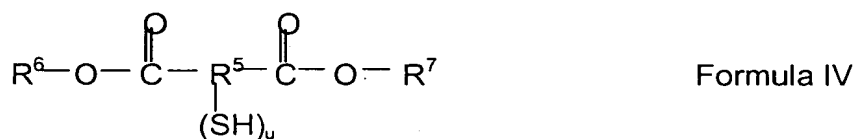
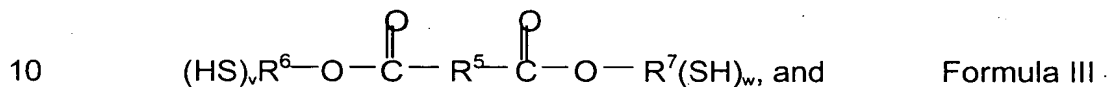
20 In a further embodiment, the organic thiols of the present invention are aliphatic esters having at least one sulfhydryl group. The aliphatic ester thiol compounds can be derived from a mono- or polycarboxylic acid and can generally be described by the formulae:



wherein R³ and each R⁴, independently, are straight chain or branched aliphatics, such as alkyls, having generally from 1 to about 20, and preferably from about 1 or 2 to about 10 carbon atoms, wherein y and z, independently, can be 0, 1, 2, to about 10 or more, wherein x is 1, 2, or an integer up to about 10. It is to be understood that all of the groups in

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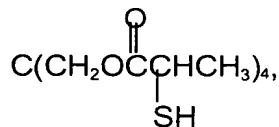
brackets do not necessarily have the same structure in a given compound. That is, for example, if x is 2 or greater, one R⁴ can independently have a different structure than another R⁴, i.e. one R⁴ can be propyl and another R⁴ ethyl. Preferred aliphatic compounds include di-ester organic thiols wherein at least one sulfhydryl substituent is attached to an aliphatic group either between the ester functional groups (acyl portion of the ester) or external thereof (alkyl portion of the ester). General formulae for representative di-ester organic thiol compounds include the following:



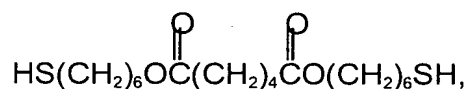
wherein R⁵, R⁶, and R⁷, independently, are straight chain or branched aliphatics, such as alkyls, having from 1 to about 20 carbon atoms, and preferably from about 2 to about 10 carbon atoms, and u, v, and w, independently, are either 0, 1, or 2, or an integer up to about 10. Independent examples of R⁵, R⁶, and R⁷ are 2-ethylhexyl, ethyl, ethylidene, butyl, butylidene, hexyl, hexylidene, decyl, and decylidene.

20 A few specific examples of compounds which can be formed from Formulae IIA, IIB, III, and IV are:

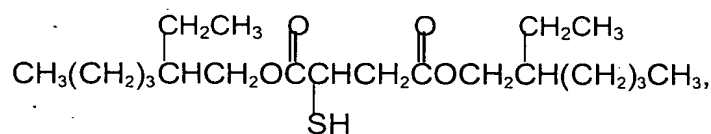
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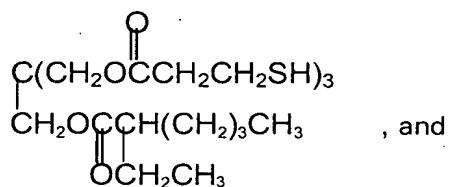
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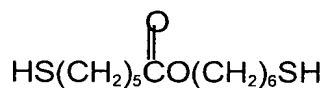
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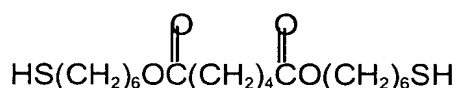
The numerous compounds described by Formulae IIA, IIB, III, and IV can be synthesized substantially as follows. A desired amount of a carboxylic acid or polycarboxylic acid which is optionally substituted with one or more sulfhydryl groups is added to a reaction vessel which is desirably equipped with a mechanical stirrer, a water separator, and a condenser. From about 0.1 to about 5 moles of an aliphatic alcohol or

polyol optionally substituted with a sulfhydryl group is added to the reaction vessel per mole of carboxyl groups. Benzene, toluene, or other suitable entraining agent for water in an amount from about 0.2 to 2.0 liters per mole of carboxyl groups, and about 0.02 to about 0.2 moles per mole of carboxylic acid, of a strong acid, i.e., one having a concentrated pH of at least 1 to about 3, such as H_2SO_4 , are added to the vessel. The mixture is heated under reflux with stirring, and the progress of the reaction can be followed by GC-MS analysis. After a period of time that depends upon the structures of the starting materials, the carboxylic acid disappears, and about 1 mole of water per mole of carboxyl groups has been collected by the water separator. Upon cooling to room temperature, the mixture is extracted with a quantity of saturated aqueous NaHCO_3 or Na_2CO_3 solution and washed with portions of water. The organic layer is dried over anhydrous MgSO_4 or other suitable drying agent, and most of the benzene is removed by rotary evaporation under aspirator vacuum at about 45-50°C. Trace amounts of residual benzene and excess aliphatic alcohol optionally substituted with a sulfhydryl group are removed by vacuum distillation at elevated temperature and about 0.01 to about 5.0 mm pressure to yield an aliphatic ester thiol as described above.

As apparent from the above description, organic thiol compounds defined by at least Formula III can be formed by utilizing sulfhydryl group substituted aliphatic alcohols, and the organic thiol compounds of at least

Formula IV can be formed by utilizing a sulfhydryl group substituted carboxylic diacid. Furthermore, compounds of Formulae IIA and IIB, wherein y and z are both positive integers, can be formed when both sulfhydryl substituted carboxylic acids or polyacids and sulfhydryl substituted aliphatic alcohols or polyols are utilized in the reaction.

Bis(6-mercaptohexyl) adipate



is an example of a compound disclosed by Formula III of the present invention, wherein R⁵ is 1,4-butyldiene, R⁶ and R⁷ are hexyl, and v and w are 1. The synthetic method for the preparation of bis(6-mercaptohexyl) adipate is as follows:

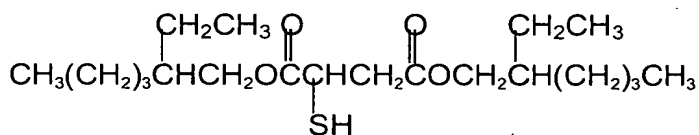
To a 1-liter round-bottom flask equipped with a magnetic stirring bar, a water separator, and a condenser were added 58.5 grams (0.400 mol) of powdered adipic acid, 110.7 grams (0.825 mol) of 6-mercapto-1-hexanol, 200 milliliters of benzene, and 1 milliliter (80 drops) of concentrated sulfuric acid. The mixture was heated under reflux with stirring, and the progress of the reaction was followed by GC-MS analysis. After 2-3 hours, the solid adipic acid had disappeared, and 15.8 milliliters (0.878 mol) of water had been collected by the water separator. Upon cooling to room temperature, the mixture was extracted with 60 milliliters of saturated NaHCO₃ solution and washed with two 100-milliliter portions of water. The organic layer was

dried over anhydrous MgSO_4 , and most of the benzene was removed by rotary evaporation under aspirator vacuum at 45-50°C. Trace amounts of residual benzene and 6-mercapto-1-hexanol then were removed by vacuum distillation at 160°C (bath temperature) and 0.5 millimeter pressure to yield

5 bis(6-mercaptohexyl) adipate as a straw-colored liquid. Yield of bis(6-mercaptohexyl) adipate, 123.6 grams (81.6%, calcd. 151.4 grams); GC purity, >95%; ^1H NMR (in CDCl_3 w/TMS, ppm): 1.54 (t, 4H, $\text{CH}_2\text{CH}_2\text{CO}_2\text{R}$), 1.26-1.66 (br, 16H, $\text{OCH}_2(\text{CH}_2)_4$), 2.10 (t, 2H, SH), 2.29 (t, 4H, $\text{CH}_2\text{CO}_2\text{R}$), 2.47 (quartet, 4H, CH_2SH), 4.00 (t, 4H, OCH_2); $\{^1\text{H}\}^{13}\text{C}$ NMR (in CDCl_3

10 w/TMS, ppm): 24.32 (C3/C6), 24.38 (C3/C6), 25.33 (C3'), 27.83 (C2/C4), 28.42 (C2/C4), 33.73 (C5/C2'), 33.78 (C5/C2'), 64.08 (C1), 172.91 (CO_2R).

Bis(2-ethylhexyl) mercaptosuccinate



is an example of a compound disclosed by Formula IV of the present invention, wherein R^5 is 1,2-ethylidene, R^6 and R^7 are 2-ethylhexyl, and u is

20 1. The synthetic method for the preparation of bis(2-ethylhexyl) mercaptosuccinate is as follows:

To a 1-liter round-bottom flask equipped with a magnetic stirring bar, a water separator, and a condenser were added 75.0 grams (0.500 mol) of

powdered mercaptosuccinic acid, 170.0 milliliters (141.6 grams, 1.087 mol) of 2-ethyl-1-hexanol, 250 milliliters of benzene, and 1 milliliter (80 drops) of concentrated sulfuric acid. The mixture was heated under reflux with stirring, and the progress of the reaction was followed by GC-MS analysis.

5 After approximately 3 hours, the solid mercaptosuccinic acid had disappeared, and about 19 milliliters (1.1 mol) of water had been collected by the water separator. Refluxing was allowed to continue overnight in order to ensure completion of the esterification. Upon cooling to room temperature, the mixture was extracted with 50 milliliters of saturated

10 NaHCO_3 solution and washed with two 100-milliliter portions of water. The organic layer was dried over anhydrous MgSO_4 , and most of the benzene was removed by rotary evaporation under aspirator vacuum at 45-50°C. Trace amounts of residual benzene and 2-ethyl-1-hexanol then were removed by vacuum distillation at 140°C (bath temperature) and 0.5

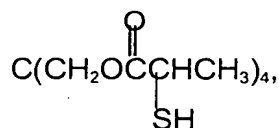
15 millimeter to yield bis(2-ethylhexyl) mercaptosuccinate as a straw-colored liquid. Yield of bis(2-ethylhexyl) mercaptosuccinate, 177.0 grams (94.5%, calcd. 187.3 grams); GC purity, >94%; ^1H NMR (in CDCl_3 w/TMS, ppm): 0.87-0.92 (br, 12H, CH_3), 1.29-1.43 (br, 16H, CH_2), 1.54-1.64 (br, 2H, CH), 2.19 (d, 1H, SH), 2.76 (d of d, 1H, $\text{CH}_2\text{CO}_2\text{R}$), 3.02 (d of d, 1H, $\text{CH}_2\text{CO}_2\text{R}$),

20 3.74-3.80 (d of quartet, 1H, $\text{CHCH}_2\text{CO}_2\text{R}$), 4.00-4.14 (m, 4H, OCH_2); $\{^1\text{H}\}^{13}\text{C}$ NMR (in CDCl_3 w/TMS, ppm): 10.93, 10.96, and 10.98 (C8), 14.03 (C6), 22.94 (C7), 23.70 (C5), 28.86 and 28.89 (C4), 30.25 and 30.30 (C3), 36.35

(CSH), 38.68, 38.69, 38.73, and 38.75 (C2), 39.87 (CH₂CO₂R), 67.30 and 67.94 (C1), 170.16 and 172.13 (CO₂R).

Pentaerythritol tetrakis(2-mercaptopropionate)

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is an example of a compound disclosed by formula IIB of the present invention, wherein R³ is pentaerythrityl, R⁴ is ethyl, x is 4, y is 1, and z is 0. The synthetic method for the preparation of pentaerythritol tetrakis(2-mercaptopropionate) is as follows:

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To a 500-milliliter round-bottom flask equipped with a magnetic stirring bar, a water separator, and a condenser were added 27.23 grams (0.200 mol) of pentaerythritol, 90.22 grams (0.850 mol) of 2-mercaptopropionic acid, 100 milliliters of toluene, and 0.5 milliliter of concentrated sulfuric acid. The mixture was heated under reflux with stirring. After about 2 days, the solid material had disappeared, and about 17 milliliters (0.94 mol) of water had been collected by the water separator. Upon cooling to room temperature, the mixture was extracted with 30 milliliters of saturated NaHCO₃ solution and washed with two 50-milliliter portions of water. The organic layer was dried over anhydrous MgSO₄, and most of the toluene and residual 2-mercaptopropionic acid were removed by distillation under vacuum. Recrystallization of the residue from ethanol gave 86.0 grams (88.4%, calcd. 97.3 grams) of pentaerythritol tetrakis(2-

mercaptopropionate) as a white solid, mp 93-96°C; ^1H NMR (in CDCl_3 w/TMS, ppm): 4.17-4.30 (AB m, 8H, CH_2O), 3.50 (pentuplet, 4H, CHSH), 2.17 (d of d, 4H, SH), 1.51 (d, 12H, CH_3); $\{^1\text{H}\}^{13}\text{C}$ NMR (in CDCl_3 w/TMS, ppm): 172.79 ($\text{C}=\text{O}$), 62.47 (CH_2O), 43.05 [$\text{C}(\text{CH}_2)_4$], 35.43 (CHSH), 20.94 (CH_3).

The organic thiol compounds disclosed by the present invention can be used as additives for polymeric compounds, wherein, for example, the organic thiols can serve as plasticizers and/or stabilizers. The organic thiols are free of metal, and desirably are not used in conjunction with any metal-based stabilizers or Lewis acids. By metal-based stabilizers it is meant any metal compound, salt, complex, or the like of any of the metals as set forth in groups 1-8 of the periodic table such as, but not limited to the heavy metals, for example cadmium, mercury, lead, and the like as well as other generally environmentally unfriendly or undesirable compounds. Examples of specific metal-based stabilizers which are avoided include those set forth in European Patent Application EP O 945 484 A1 at least on page 3 thereof. Accordingly, the polymer compositions of the present invention are substantially free of the various metal-based stabilizers, and contain generally less than about 2 parts, desirably less than about 1 part, and preferably less than about 0.5 part by weight or are entirely free thereof, based upon 100 total parts by weight of the one or more halogen-containing polymers or copolymers. The polymer compositions of the

present invention are also generally substantially free of various Lewis acids such as boron trifluoride, aluminum chloride, zinc chloride, methyltin trichloride, dibutyltin dichloride, and the like. Such acids when contained in the polymeric composition are generally less than about 0.5 part, desirably less than about 0.1 part, and preferably less than about 0.01 part by weight per 100 total parts by weight of all halogen-containing polymers or copolymers.

The polymers utilized in the present invention include any organic chlorine- or bromine-containing polymers or resins in which the halogen is attached directly to a carbon atom. Polymers and/or monomers thereof useful to the present invention include, but are not limited to, poly(vinyl chloride) (PVC), poly(vinylidene chloride), poly(vinyl bromide), poly(vinylidene bromide), chlorinated poly(vinyl chloride), chlorinated polyethylene, chlorinated natural or synthetic rubber, polychloroprene, rubber hydrochloride, or chlorinated polystyrene, and combinations and copolymers thereof. The molecular weight of such polymers can vary over a wide range, and they generally have a number average molecular weight of from about 5,000 to about 1,000,000, or from about 10,000 to 100,000 for poly(vinyl chloride). Such polymers can also contain other plasticizers in addition to the compounds of the present invention, and where appropriate, such polymers can be plastisols, organisol, and the like.

The above noted chlorine- or bromine-containing polymers are made from monomers forming the same such as vinyl chloride, vinylidene chloride, and the like, or are a copolymer made from a mixture of monomers comprising, desirably, at least about 70% by weight of vinyl chloride, based on the total monomer weight. Examples of the copolymers include those made from vinyl chloride and from about 1 to about 30% of a copolymerizable ethylenically unsaturated monomer such as vinyl acetate, vinyl butyrate, vinyl benzoate, vinylidene chloride, diethyl fumarate, diethyl maleate, other alkyl fumarates and maleates, vinyl propionate, methyl acrylate, 2-ethylhexyl acrylate, butyl acrylate and other alkyl acrylates, methyl methacrylate, ethyl methacrylate, butyl methacrylate and other alkyl methacrylates, methyl alpha-chloroacrylate, styrene, trichloroethylene, vinyl ethers such as vinyl ethyl ether, vinyl chloroethyl ether and vinyl phenyl ether, vinyl ketones such as vinyl methyl ketone and vinyl phenyl ketone, 1-fluoro-2-chloroethylene, acrylonitrile, chloroacrylonitrile, allylidene diacetate, and chloroallylidene diacetate. Typical copolymers include vinyl chloride-vinyl acetate (e.g. 96:4 sold commercially as VYNW), vinyl chloride-vinyl acetate (e.g. 87:13), vinyl chloride-vinyl acetate-maleic anhydride (e.g. 86:13:1), vinyl chloride-vinylidene chloride (e.g. 95:5), vinyl chloride-diethyl fumarate (e.g. 95:5), and vinyl chloride-2-ethylhexyl acrylate (e.g. 80:20).

Preferred polymers include poly(vinyl chloride) and poly(vinyl bromide). Preferred copolymers include vinyl chloride-vinyl acetate, vinyl chloride-vinylidene chloride, and other vinyl chloride copolymers.

5 The organic thiol compounds according to the present invention can be added to or blended with the above described polymers in any suitable amount, generally from about 1 to about 100 parts by weight per 100 total parts by weight of all of the one or more polymers or copolymers, depending on the desired properties of the final product such as being plasticized. As stated above, the organic thiol compounds of the present
10 invention are particularly suitable for serving as both stabilizers and plasticizers. A semi-rigid composition of the present invention would desirably contain from about 1 to about 25 parts of the organic thiol compound per 100 parts by weight of a polymer defined above. A flexible composition of this invention contains from about 25 to about 100 parts of
15 the organic thiol compound per 100 parts of polymer utilized in the present invention. The organic thiol compounds can be incorporated into the resin by any one of many known methods that provide for uniform distribution of additives throughout resin compositions, such as, for example, mixing in an appropriate mill, mixer, or Banbury apparatus.

20 Depending on the end use, further additives in conventional or suitable amounts, known to the art and to the literature or to those of ordinary skill in the art, can be added to the above noted polymers, such as

certain other stabilizers and costabilizers, lubricants, plasticizers, extenders, impact modifiers, fillers, pigments, antioxidants, dyes, ultraviolet light absorbing agents, densifying agents, and the like.

Advantageously, it has been found that the addition of epoxidized soybean oil (ESO) to compositions of the present invention increases the effectiveness of the organic thiols, especially the aliphatic organic thiols. Generally, epoxidized soybean oil is utilized in chlorine- or bromine-containing polymers as an HCl scavenger. Epoxidized soybean oil can be utilized in compositions of the present invention in an amount generally from about 1 to about 30 parts, desirably from about 2 to about 20 parts, and preferably from about 3 to about 10 parts by weight per 100 parts by weight of chlorine- or bromine-containing polymer. The advantageous effect obtained by utilizing both epoxidized soybean oil and the organic thiols of the present invention can be seen in the results listed in Table 4 hereinbelow, wherein it is shown that both the dynamic heat stability and decomposition time are improved when compared to those of compositions without the above stated compounds.

As stated above, the organic thiols greatly enhance the heat stability of halogenated resins, which are known to undergo rapid thermal degradation under the conditions found in the processes to which these resins are subjected, such as, for example, calendering, extrusion, injection molding, and end usage at elevated temperatures. For example, poly(vinyl

chloride) is known to undergo a rapid and sequential elimination of hydrogen chloride, or dehydrochlorination, at elevated process temperatures. Other halogenated resins are known to undergo similar dehydrohalogenation reactions. Dehydrochlorination in PVC can initiate at labile chlorines that are associated with irregularities in the molecular chain, such as branches or double bonds. Once free, the HCl promotes further degradation of the poly(vinyl chloride) through unzipping of additional hydrogen chloride from the polymer chain. The primary functions of heat stabilizers in PVC are to depress hydrogen chloride elimination and discoloration. In addition to functioning as heat stabilizers, the organic thiols of the present invention are often effective plasticizers and frequently serve or function as both a heat stabilizer and a plasticizer. Thus, in many polymer compositions such as PVC, organic thiols of the present invention serve as heavy-metal-free or metal-based-free stabilizers and plasticizers, a unique combination.

The organic thiols of the invention thus unexpectedly improve the processing properties of the polymers, further providing cost and efficiency improvements to resin processors. The disclosed thiols also do not cause odor problems associated with the processing of resins stabilized thereby and provide greatly increased resistance to resin yellowing associated with thermal degradation.

It is to be understood that both the aromatic and aliphatic organic thiols of the present invention can contain one or more substituents thereon, including but not limited to, alkoxy groups, ester groups such as carboethoxy or carbomethoxy, and halides such as chlorine, fluorine, bromine, and iodine. That is, various functional groups, such as those listed above, which do not react with the ester linkage or sulfhydryl groups can be utilized.

The following examples serve to illustrate, but not to limit, the present invention.

EXAMPLES

Example 1:

An intimate mixture of PVC and di(2-ethylhexyl) 5-mercaptisophthalate (0.044 mole per mole of PVC monomer units) was heated under argon at 170°C for 1.5 hours. At the end of the heating period, the mixture retained its initial white color.

Example 2:

An intimate mixture of PVC and pentaerythritol tetrakis(2-mercaptopropionate) (0.038 mole per mole of PVC monomer units) was heated under argon at 175-180°C for 2.0 hours. At the end of the heating period, the mixture retained its initial white color.

Example 3: (Control)

An intimate mixture of PVC and 1-dodecanethiol (0.044 mole per mole of PVC monomer units) was heated under argon at 170°C for 1.5 hours. At the end of the heating period, the mixture was dark red-brown in color, a result that was indicative of extensive degradation.

Example 4:

The following Table 3 is a comparative evaluation of the organic thiol bis(2-ethylhexyl) 5-mercaptoisophthalate in a typical poly(vinyl chloride) composition with current commercially utilized stabilizers.

The formulations evaluated (A-F) were prepared by standard blending methods that are well-known to those skilled in the art. Properties of these formulations were determined by the standard ASTM methods that are identified under the heading "Test Description". The measurements reported show that the thiol plasticizer/stabilizer gave physical properties to the formulations which were comparable to those obtained with the common commercial plasticizer, DOP. Thus it is apparent that the thiol can function as the primary plasticizer for PVC without the need for additional plasticization. Moreover, the data in Table 3 show that the dynamic and static heat stability conferred by the thiol are equal to or better than those obtained with traditional amounts of commercial lead or barium-zinc heat stabilizers. Further, the tabulated data reveal that the stability obtained with the thiol can be achieved without the incorporation of an epoxidized

soybean oil costabilizer. Finally, the data for formulations E and F indicate that the thermal stabilization effects of the thiol and the barium-zinc stabilizer are antagonistic, rather than additive or synergistic.

Table 3

Evaluation of Bis(2-ethylhexyl) 5-Mercaptoisophthalate in a Typical Poly(vinyl chloride) Composition

Ingredient Description	A(control)	B(control)	C	D	E	F
OxyVinyls 455F (PVC)	100.00	100.00	100.00	100.00	100.00	100.00
DOP (Plasticizer)	30.00	30.00	--	--	--	30.00
Thiol Plasticizer/Stabilizer (Bis(2-ethylhexyl) 5-mercaptoisophthalate)	--	--	35.00	30.00	30.00	5.00
Epoxidized Soybean Oil (HCl scavenger)	5.00	5.00	--	5.00	5.00	--
General Purpose Ba/Zn Liquid (Stabilizer)	3.00	--	--	--	3.00	3.00
Dyhal/Tribase Blend (Lead stabilizer)	--	4.00	--	--	--	--
Stearic Acid (Processing lubricant)	0.10	0.10	0.10	0.10	0.10	0.10
Total (Parts by weight)	138.10	139.10	135.10	135.10	138.10	138.10
Test Description	A	B	C	D	E	F
Hardness, Shore C (ASTM D 2240-86)	85/74	86/75	94/85	94/86	95/91	86/75
Specific Gravity (ASTM D 792-91)	1.27	1.3	1.29	1.29	1.29	1.27
Tensile Strength, PSI (ASTM D 638-91)	3315	3472	3467	3421	3218	3322
Elongation, % (ASTM D 638-91)	338	305	281	328	306	341
Dynamic Heat Stability, 205°C, 100 RPM, #5 Bowl, Minutes (ASTM D 2538-95)	24	60	60	60	60	3
Initial Yellow, 210°C, Minutes (ASTM D 2115-92)	15	10	10	10	15	15
Decomposition Time, 210°C, Minutes (ASTM D 2115-92)	45	>60	>60	>60	25	20

Table 4

Evaluation of Aliphatic Ester Thiols in a Typical Poly(vinyl chloride) Composition

Ingredient Description	Control 1	Control 2	Trial 1	Trial 2	Trial 3	Trial 4
OxVinyls 455F	100.00	100.00	100.00	100.00	100.00	100.00
DOP	30.00	30.00	--	--	--	--
Thiol - Adipate	--	--	35.00	30.00	--	--
Thiol - Succinate	--	--	--	--	35.00	30.00
Epoxidized Soybean Oil	5.00	--	--	5.00	--	5.00
General Purpose Ba/Zn Liquid	3.00	--	--	--	--	--
Dythal/Tribase Blend	--	4.00	--	--	--	--
Stearic Acid	0.10	0.10	0.10	0.10	0.10	0.10
Total (Parts by weight)	138.10	134.10	135.10	135.10	135.10	135.10
Hardness, Shore C (ASTM D 2240-86)	85/75	91/85	70/60	70/60	80/72	80/73
Specific Gravity (ASTM D 792-91)	1.27	1.32	1.3	1.3	1.27	1.27
Tensile Strength, PSI (ASTM D 638-91)	3482	3725	3759	3630	3588	3504
Elongation, % (ASTM D 638-91)	327	288	262	259	311	342
Dynamic Heat Stability, 205°C, 100 RPM, #5 Bowl, Minutes (ASTM D 2538-95)	19	29	57	58	>60	>60
Initial Yellow, 210°C, Minutes (ASTM D 2115-92)	15	10	15	15	15	15
Decomposition Time, 210°C, Minutes (ASTM D 2115-92)	45	60	>60	>60	50	>60

Example 5: Aliphatic Ester Thiol Compounds

As can be seen in Table 4, the aliphatic ester thiol compounds of the present invention were evaluated and directly compared to two control formulations composed of conventional plasticizers and stabilizers. The results show that both of the ester thiols are very good plasticizers, with the adipate thiol actually being more efficient as a plasticizer than DOP. Moreover, both of the ester thiols conferred dynamic and static heat stability to the formulations that were equal to or greater than those achieved with conventional amounts of commercial lead or barium-zinc stabilizers. When the succinate thiol was used, the static heat stability also was improved by the incorporation of 5 parts by weight of epoxidized soybean oil, which is well-known to be a scavenger for HCl. Furthermore, when used together with either the adipate thiol or the succinate thiol, the epoxidized soybean oil tended to prevent the formation of small bubbles in the test specimens during the static heat stability test. Neither of the aliphatic ester thiols caused strong or offensive odors during compounding or testing operations.

In accordance with the patent statutes, the best mode and preferred embodiments have been set forth, and the scope of the present invention is not limited thereto, but rather by the scope of the attached claims.